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The MPMMCC Varanasi Glove Phantom

A Minimal-Cost, Instantly Fabricable Ultrasound Training Phantom for In-Plane Needle Guidance Practice in Anaesthesia Residency

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ABSTRACT

Background. Ultrasound-guided regional anaesthesia (UGRA) and ultrasound-guided vascular access (UGVA) require hand-eye coordination skills best acquired through deliberate practice. Commercial training phantoms are costly, have limited availability in low-resource settings, and are often inaccessible at the point of teaching. A freely replicable phantom requiring only materials available in any operating theatre (OT) would substantially lower the barrier to simulation-based UGRA and UGVA training.

Description. We describe the MPMMCC Varanasi Glove Phantom, constructed entirely from OT-standard consumables: a non-sterile latex examination glove size small, two bundles of 8-ply gauze (10 cm × 10 cm), tap water, three short segments of IV infusion tubing, and a transparent film adhesive dressing. Assembly requires no tools, no sterile technique, and fewer than five minutes. The phantom provides a sonographically credible soft-tissue analogue with embedded tubular targets for in-plane needle guidance practice using a high-frequency linear transducer and an 18G intravenous cannula or 100 mm echogenic needle.

Acoustic basis. Tap water serves as the principal anechoic medium (acoustic impedance ≈1.48 MRayl). Compact, un-spread 8-ply gauze rolls produce a heterogeneous fibrous matrix that generates diffuse hyperechoic background scatter approximating soft tissue. The latex glove wall acts as a specular fascial reflector. IV tubing segments appear as hypoechoic cylinders with posterior acoustic enhancement, simulating a neurovascular bundle. The outer film dressing eliminates the air–latex interface, enabling standard coupling gel application and also acts as a one-way-valve to reduce puncture site leakage.

Application. The phantom supports needle-tip tracking, bevel-orientation recognition, target acquisition, and the full cannula-over-needle procedural sequence. Estimated material cost is under ₹50 (USD 0.54) per unit at standard OT procurement prices.

Conclusion. The MPMMCC Glove Phantom achieves the essential goals of a Category I low-fidelity task trainer at effectively zero marginal cost. It is immediately replicable in any teaching hospital and is offered to the global anaesthesia education community under CC BY-NC 4.0.

Keywords: *ultrasound-guided regional anaesthesia · simulation · low-fidelity phantom · needle guidance · task trainer · low-resource education · anaesthesia residency*

1. MATERIALS

All components are standard OT consumables routinely stocked in Indian public-sector tertiary hospitals. No procurement, no requisition, and no preparation time beyond the assembly itself is required.

Component	Specification	Qty	Acoustic / Functional Role
Non-sterile latex examination glove	Standard medium size	1	Watertight container; glove wall provides specular fascial reflection
8-ply gauze swab	10 cm × 10 cm, packed (not spread)	2 bundles	Fibrous heterogeneous matrix; diffuse hyperechoic soft-tissue analogue
Tap water	Room temperature	~250 mL	Anechoic medium; acoustic impedance ≈1.48 MRayl (cf. tissue 1.5–1.7 MRayl)
IV infusion set tubing segments	5 cm lengths, standard IV set	3	Hypoechoic cylinders with posterior enhancement; neurovascular bundle surrogates
Transparent film adhesive dressing	IV site dressing 5×7 cm OR transparent stretch adhesive bandage (e.g. cut from 10 cm × 5 m roll, of after-tattoo-bandage)	1–3 pieces	Eliminates air–latex interface; enables coupling gel; mechanical protection
Ultrasound coupling gel	Standard USG gel	As needed	Acoustic coupling between transducer and phantom surface
18G IV cannula or 100 mm echogenic needle	Standard cannula-over-needle or 100 mm echogenic needle	Per session	Training needle; generates strong specular reflection on high-frequency probe

Table 1. Bill of materials for one MPMMCC Varanasi Glove Phantom unit. Estimated total material cost: <₹50 (USD 0.54) at Indian public-sector OT procurement prices (April 2026). Excludes the cost of USG coupling gel, and echogenic needle and USG machine.

2. FABRICATION PROTOCOL

The following steps may be completed by a single person in under five minutes without any tools, sterile technique, or prior training in phantom construction.

Step 1 — Load the gauze. Place both 10 cm × 10 cm gauze bundles inside the glove, maintaining their rolled/packed configuration. Do not unfold or spread the gauze. Compact, layered gauze preserves the fibrous heterogeneity that generates the desired hyperechoic scatter pattern. Spread gauze produces an artificially uniform reflector and should be avoided.

Step 2 — Insert the tubing targets. Place three 5 cm segments of IV infusion set tubing among the gauze bundles, orienting them parallel to the long axis of the glove. Recommended arrangement: two tubes adjacent (4–5 mm apart) and one offset by approximately 5 mm laterally, mimicking an artery-vein-nerve triad. This arrangement forces the trainee to discriminate between targets before needling.

Step 3 — Fill with water. Hold the glove upright (fingers pointing down) and pour tap water slowly into the wrist opening until filled to the brim, holding the whole assembly inside a water filled bucket. Pour in a thin, slow stream to allow entrapped air to escape progressively. Eliminate any residual air bubbles by gently squeezing the glove while continuing to fill.

Step 4 — Seal the glove. Holding the whole assembly underneath water (within the water filled bucket), tie a secure overhand knot using the wrist portion of the glove itself, as close to the water surface as possible to minimise dead-space air.

Step 5 — Dry and dress the surface. Dab the outer surface dry with a gauze swab. Apply the transparent film adhesive dressing to the dorsal (flat) surface. Smooth from the centre outward to prevent air bubble entrapment. The dressing eliminates the air–latex interface and provides mechanical reinforcement.

Step 6 — Deploy. Place the assembled phantom flat on a procedure tray, dressed surface upward. Apply standard ultrasound coupling gel. Ready for use with a high-frequency linear transducer (7.5–15 MHz).

A scalp vein set may be used to refill the glove phantom with water from time to time, as the water slowly oozes out from multiple puncture sites after previous practice sessions.

Figure 1. Materials gathered and used for fabrication of the MPMMCC Varanasi Glove Phantom at 13:19 hours on 10th April 2026

Figure 2. In-plane needling practice on the MPMMCC Varanasi Glove Phantom by JR2 Anesthesia at 13:37 hours, 10 April 2026

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Figure 3. In-plane needling practice on the MPMMCC Varanasi Glove Phantom by JR2 Anesthesia at 13:39 hours, 10 April 2026

3. ACOUSTIC BASIS

The phantom achieves clinically useful sonographic fidelity through the complementary acoustic properties of its individual components. No single component is novel; the design insight lies in their combination.

Component	Acoustic Property	Clinical Analogue	Design Rationale
Tap water	Anechoic; acoustic impedance ≈1.48 MRayl	Tissue fluid, lymphatic channels	Closest freely available approximation to the fluid environment surrounding fascial planes
Compact 8-ply gauze	Heterogeneous fibrous matrix; diffuse hyperechoic scatter	Loose connective tissue, fat lobules, muscle fasciculi	Preserving the rolled, unspread form is critical; spreading creates acoustic homogeneity
Latex glove wall	Specular reflector at impedance boundary	Fascia, epineurium, vessel adventitia	Naturally thin and taut when water-filled, producing a crisp linear reflector
IV tubing segment	Hypoechoic cylinder; posterior acoustic enhancement	Artery, vein, nerve sheath	Internal air or fluid column of the tube provides reliable posterior enhancement—a key vessel identification feature
Film dressing	Eliminates air–latex interface. One way valve for minimizing leak.	N/A (artefact suppressor)	Air produces near-total acoustic reflection; the dressing replaces it with an acoustically transmissive solid
18G IV cannula / 100 mm echogenic needle	Strong specular reflector; echogenic tip and shaft	Clinical RA needle, clinical vascular access needle	Gauge sufficient to produce a clear artefact; realistic procedural sequence including stylet withdrawal

Table 2. Acoustic basis of each phantom component and its clinical analogue.

4. TRAINING APPLICATIONS

The phantom is designed as a Category I low-fidelity task trainer. Its goal is *not* anatomical realism but procedural skill transfer at the critical bottleneck of first-exposure ultrasound-guided needling: hand-eye coordination between transducer and needle under real-time image guidance. The following skills can be meaningfully practised in a single session:

Skill	Description	Fidelity
Needle-tip tracking	Maintaining the needle tip in the ultrasound beam while advancing; correcting out-of-plane drift	High
Bevel orientation	Distinguishing bevel-up (hyperechoic artefact) from bevel-down orientation on the image	High
Target acquisition	Advancing needle tip to contact a specific tubing target without disturbing adjacent targets	High
Probe–needle coordination	Simultaneous probe and needle movement; maintaining in-plane alignment during redirection	High
Full cannula sequence	Target contact → confirm tip position → withdraw stylet → advance catheter	Moderate
Neurovascular discrimination	Identifying and avoiding the ‘vessel’ targets before needling the ‘nerve’ target	Low–Moderate

Vessel compressibility	Not supported; tubing does not compress	Not applicable
Fascicular nerve pattern	Not supported; tube simulates sheath only, not internal honeycomb	Not applicable

Table 3. Trainable skills and fidelity assessment for the MPMMCC Varanasi Glove Phantom.

For maximal educational yield, the tubing targets should be arranged deliberately before phantom assembly. The recommended triangular arrangement forces the trainee to identify and avoid the simulated vessel before needling the simulated nerve target, mirroring the cognitive sequence of actual UGRA.

5. LIMITATIONS

Vessel compressibility. The tubing segments do not compress under transducer pressure. Vein–artery discrimination by compressibility cannot be practised. This should be supplemented by dedicated exercises on a vascular phantom before clinical transition.

Nerve fascicular architecture. The IV tubing simulates a nerve sheath but not the internal honeycomb (fascicular) pattern. Recognition of intraneural needle placement cannot be reliably trained on this phantom.

Needle-pass durability. Repeated latex puncture creates cumulative leak tracks. The phantom maintains integrity for approximately 10–20 passes. A scalp vein set may be used to refill the glove phantom with water from time to time, as the water slowly oozes out from multiple puncture sites after previous practice sessions.

Tissue stiffness. The water-filled latex does not replicate the viscoelastic layered stiffness of real tissue. Tactile feedback during needle advancement through fascial planes is not reproducible.

Depth calibration. The phantom does not provide fixed reference depths and should not be used to calibrate depth estimation for specific anatomical targets.

No injection feedback. Hydrodissection appearance and injectate spread patterns cannot be reliably assessed, as the water medium does not replicate tissue pressure and compliance.

6. DISCUSSION

Commercial ultrasound training phantoms range in cost from USD 300 or about 28000 INR (basic block phantoms) to USD 3,000 or about 2,80,000 INR (advanced multi-tissue models). Even at the lower end, acquisition cost, maintenance, and institutional procurement processes represent substantial barriers in low- and middle-income country (LMIC) teaching hospitals. The MPMMCC Varanasi Glove Phantom addresses this barrier directly: the entire construct costs less than a single pair of surgical gloves.

The design philosophy is one of functional minimalism. Rather than approximating tissue in every acoustic parameter, the phantom identifies the single skill bottleneck for first-exposure UGRA and UGVA trainees — maintaining in-plane needle-tip visibility during target approach — and delivers sufficient fidelity to train exactly that skill. This mirrors the evidence base for low-fidelity simulation, which demonstrates that task-specific skill transfer does not require high anatomical realism.

The critical fabrication insight — maintaining gauze bundles in their rolled, packed configuration — deserves emphasis. Spread gauze produces a uniform acoustic reflector that does not approximate soft tissue scatter. The heterogeneity of the compact roll is the essential property, and it is destroyed by unfolding.

The transparent film dressing resolves what would otherwise be the phantom's most significant acoustic limitation: the air–latex interface at the probe contact surface. The aftercare tattoo bandage roll format (10

cm × 5 m, approximately ₹150–200 for the full roll) offers a particularly economical option, providing sufficient material for dozens of phantoms from a single purchase.

7. SUGGESTED SESSION PROTOCOL

The following protocol is suggested for a first-exposure in-plane needling session. Each trainee should have their own phantom. Duration: approximately 20–30 minutes.

Phase	Duration	Task	Endpoint
1 — Orientation	5 min	Scan the phantom without a needle. Identify gauze matrix, tubing targets, glove wall. Measure apparent depth of each tube.	Correct identification of all three tubes
2 — Needle introduction	5 min	Insert 18G cannula / 100 mm echogenic needle with probe held stationary. Achieve first visualisation of needle tip.	Unambiguous tip visualisation on first attempt
3 — Target approach	10 min	Advance needle tip to contact the deepest tube, then each remaining tube in sequence without withdrawing from the phantom.	Contact all three tubes in ≤5 needle passes
4 — Full sequence	5 min	Advance to target tube, confirm tip position, withdraw stylet, advance catheter, confirm catheter position on image.	Catheter tip at target on USG image
5 — Debrief	5 min	Supervisor reviews key still images. Discuss probe–needle alignment errors, tip loss, bevel orientation.	—

Table 4. Suggested first-exposure in-plane needling session protocol using the MPMMCC Varanasi Glove Phantom.

8. CONCLUSION

The MPMMCC Varanasi Glove Phantom demonstrates that the primary prerequisite for simulation-based UGRA and UGVA training — a sonographically credible medium with visible needle targets — can be met entirely with materials already present in any operating theatre. The design is not a compromise imposed by resource constraints but a deliberate act of functional reduction: it provides exactly the fidelity required for the specific competency it targets, and no more.

At under ₹50 (USD 0.54) per unit, the phantom is economically equivalent to a disposable consumable. It can be assembled during a tea break, used for a full teaching session, and discarded without loss. The absence of procurement, storage, sterilisation, and maintenance requirements removes every institutional barrier to adoption.

This design is offered to the global anaesthesia education community under CC BY-NC 4.0 International. You may reproduce, adapt, and distribute it freely for non-commercial educational purposes, provided attribution is given.

DECLARATIONS

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Ethics	This is a technical description of a non-biological training device. No human subjects, patient data, or biological material is involved. Institutional ethics review is not applicable.
Data availability	All data and materials described in this paper are fully specified in the text. No additional data sets were generated.
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SUGGESTED CITATION

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